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1) THE EVOLUTION OF CTB109

2) A STUDY OF THE COMPOSITE REMNANT MSH15-56

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Annual Report

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The NASA Technical Officer for this grant is Dr. Nicholas White, Code 668, Laboratory for High Energy Astrophysics, NASA/Goddard Space Flight Center, Greenbelt, Maryland 20771.

The subject grant is for the analysis of *ASCA* observations of two well-known galactic Supernova Remnants, CTB 109 and MSH 15-56. The purpose of the proposal is to study spectral differences as a function of position within each of the remnants. For CTB 109 we are attempting to understand how the unusual semi-circular structure evolved. For MSH 15-56, we are attempting to understand the nature of the emission in the bright central region and around the outer edge of the remnant.

CTB 109

The *ASCA* observations of the SNR CTB109 were conducted in November 1995. Three pointings were made covering different regions of this large remnant. Unfortunately, one of the pointings was 4 arcminutes away from the intended direction due to a ground station commanding error (an unfortunate but not fatal error). The instruments performed well and yielded good data. The data were sent to us on DAT tape and were copied onto disk. We performed the preliminary processing on the data to extract the data from times when the background rates were low. Preliminary analysis indicates that spectra from each of the three regions cannot be well-fit with a single temperature Raymond-Smith model.

MSH 15-56

The *ASCA* observation of the SNR MSH15-56 was conducted in June and August of 1995. The spacecraft pointing was nominal and the instruments performed well and yielded good data. The data were sent to us on DAT tape and were copied onto disk. We performed the preliminary processing on the data to extract the data from times when the background was low. An error in the standard processing produced confusing output, indicating that the data quality had been compromised. After consultation with the *ASCA* GOF, the problem was diagnosed as a simple SW bug and the data were verified to be of high quality. This has delayed further work on these data.

Analysis

We have been working vigorously on the MSH15-56 data analysis. We have created exposure-corrected images in the several energy bands using both the *ASCA* GOF SW and the image processing SW produced by Churazov, E., Gilfanov, M., Forman, W., and Jones, C. This analysis revealed that there is a distinct, localized region of hard X-ray emission which lies along a ridge of radio emission. This is particularly interesting because a pulsar has not been detected in this remnant to date and this identifies a new region of the remnant to be searched. The X-ray spectrum of this region is approximately 8-% thermal and 20% non-thermal while the rest of the remnant is completely thermal. There is no X-ray point source detected in this region in the ROSAT data; we will search the *ASCA* emission for variability. We have discussed our results with several radio astronomers both from the standpoint of the pulsar search and the overall structure of the remnant. Other searches for the pulsar have been conducted and come up negative while there is exciting new, higher resolution radio data which when processed will be extremely valuable to compare with the X-ray data.

Travel

The funding was used to support the travel of the PI to the Minnesota Astronomy Centennial on the evolution of shell-type SNRs. The PI presented a poster on this analysis and had many fruitful discussions with other astronomers at this meeting.

MINNESOTA ASTRONOMY CENTENNIAL

10⁵¹ ERGS: THE EVOLUTION OF SHELL SNRs

POSTER SESSION

Session 1: Very Young Remnants

1.01

Laboratory Simulation of Hydrodynamic Phenomena in Supernova Remnants

R. Paul Drake (U. Michigan), S. Gail Glendinning (Lawrence Livermore National Lab), Kent Estabrook (LLNL), Richard McCray (U. Colorado), Bruce Remington (LLNL), A.M. Rubenchik (U.C. Davis), E. Liang (Rice) R. London (LLNL), R.J. Wallace (LLNL), J. Kane (U. Arizona)

We are developing experiments[1] using the Nova laser to investigate hydrodynamic phenomena relevant to supernova explosions[2] and to SNRs. Our aim is to provide tests of the computational models now used to interpret the astrophysical observations, and also to provide data that suggests directions for their improvement. In experiments relevant to Very Young SNRs, we are investigating the evolution of the hydrodynamic assembly formed by the collision of high-Mach-number ejecta with ambient plasma. This is motivated by modeling of SN1987A. The aim is to improve the predictions of the impending collision between such an assembly and the nebular ring. Further experiments will produce radiative hydrodynamic systems. These will be relevant to remnant formation in the more typical Type II SN having a denser circumstellar medium. The SNR experiments and their connections to modeling will be discussed. (Work supported by the US Department of Energy.) [1] B.A. Remington et al., in press, Phys. Plasmas (May, 1997) [2] J. Kane et al., in press, Ap. J. Lett. (March-April, 1997).

1.02

The Nature of Recent Radio Supernovae

Schuyler D. Van Dyk (Visiting scientist at UCLA), Marcos J. Montes (NRC/NRL), Richard A. Sramek (NRAO/VLA), Kurt W. Weiler (NRL), Nino Panagia (ESA/STScI)

The radio emission from supernovae (SNe) is nonthermal synchrotron radiation of high brightness temperature, with a "turn-on" delay at longer wavelengths, power-law decline after maximum with index β , and spectral index α asymptotically decreasing with time to a final, optically thin value. Radio supernovae (RSNe) are best described by the Chevalier (1982) "mini-shell" model, with modifications by Weiler et al. (1990). RSNe observations provide a valuable probe of the SN circumstellar environment and progenitor system. We present a progress report on the nature of the recent Type IIb SNe 1993J and 1996cb, and of the Type Ic SN 1994I.

1.03

Radio Emission from Supernovae

S.D. Van Dyk (UCLA), M.J. Montes (NRC/NRL), K.W. Weiler (NRL), R.A. Sramek (NRAO-VLA), N. Panagia (STScI/ESA), R. Park (TJHS)

Radio supernovae (RSNe) are an excellent means of probing the circumstellar matter around, and therefore the winds from, supernova (SN) progenitor stars or stellar systems. The observed radio synchrotron emission is best described by a modified Chevalier model which involves the generation of relativistic electrons and enhanced magnetic field through the SN shock interacting with a relatively high-density circumstellar envelope, presumed to have been established through mass loss in the late stages of stellar evolution.

Since the detection of SN 1979C in 1980, extensive data have been collected and analyzed for two dozen RSNe.

shells in these remnants have recently gone radiative, thus leaving only the hot interior to persist in X-rays. Another suggestion is that the central emission measure has been enhanced by the presence of cool clouds left relatively intact after the passage of the blast wave to slowly evaporate in the hot remnant interior. We have applied models for these scenarios to the X-ray brightness and temperature profiles for the center-filled SNRs MSH 11-61A and W28. Here we report on the results of this study and discuss the age, energy, and density characteristics implied by the models for these remnants.

5.03

Excitation and disruption of a molecular cloud by the 3C391 supernova remnant

Rho, J.-H. (CEA-Saclay, France) and Reach, W. T. (IAS-Orsay, France)

The interactions with clouds, which possibly provide evaporating clouds, are being confirmed in infrared and millimeter wavelengths for 3C391 and W44. The brightness of the [OI] $63\ \mu\text{m}$ line, an energy tracer, was $\sim 0.3 - 1.4 \times 10^{-3}\ \text{erg cm}^{-2}\ \text{sr}^{-1}$, detected in the 20 positions observed toward both remnants. The lines of 3C391 and W44 are brightest strongly peaked, at the edges of the remnants, which brightness suggest pre-shock densities $> 10^3\ \text{cm}^{-3}$ and ram pressures of order $10^{-7}\ \text{dyne cm}^{-2}$, compared with theoretical models (e.g. Hollenbach & McKee 1989), as might occur for a supernova blast wave interacting with a molecular cloud. Continuum emission toward the remnant, expected from dust heated by the shock is detected. The radiative energy loss infers that the remnants are in Sedov Stage, rather than a radiative phase. We have also mapped a molecular cloud, into which the shock front of the SNR 3C391 is currently impacting, in three lines of CS simultaneously, HCO+ and 12CO ($J=2-1$) using IRAM 30m telescope, in order to study the excitation of molecular gas by a fast shock. We detected a broad wing in all CS lines as well as in HCO+, which are as broad as that of the only other clear example of molecular shock in IC443. With our map of the CS line ratio, we will present if there are pre-existing dense condensations in the pre-shock cloud, which survive the initial blast wave and evaporate inside the remnant, and if it can explain the center-filled X-ray emission.

5.04

ASCA Observations of MSH15-56

Paul Plucinsky (Smithsonian Astrophysical Observatory)

We present ASCA observations of the SNR MSH15-56. MSH15-56 is an example of a remnant which defies classification schemes; it is a "composite" SNR in the radio and has a complex X-ray morphology consisting of a partial shell and a bright, central enhancement. The remnant has the classic composite morphology in the radio consisting of a compact central region with a non-thermal spectrum with $\alpha = -0.1$ and an outer shell, also with a non-thermal spectrum but with a significantly steeper spectrum, $\alpha = -0.4$. The X-ray enhancements are not spatially coincident with the central radio enhancement; but they curiously lie on either side of the radio enhancement. The ASCA data show that the X-ray emission from the central region is completely thermal, while the emission from the SW shell is a mixture of thermal and non-thermal components, with the non-thermal component accounting for about 20% of the spectrum from the central region is well-fitted by an equilibrium, Raymond-Smith model with solar abundances and the spectrum from the SW shell is well-fitted by an equilibrium, Raymond-Smith and a power-law model. There is some evidence for an overabundance of Si in the central region. We will discuss possible explanations for the existence of the non-thermal component in the SW shell and also compare the ASCA data with the ROSAT data to better determine the overall structure and evolutionary state of the remnant.

5.05

Study of the Composite Remnant MSH 11-62

Harris (Harvard-Smithsonian Center for Astrophysics), Dr. John Hughes (Rutgers U.), Dr. Patrick Slane (Harvard-Smithsonian Center for Astrophysics)

We present an analysis of the X-ray data collected during an observation of the supernova remnant (SNR) MSH 11-62 by the *Advanced Satellite for Cosmology and Astrophysics* (ASCA). We show that MSH 11-62 is a composite